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(54) A device for determining the wind energy in order to control wind generators

(57) The device pressure probes (10) mounted at the surface of the rotor blades (4) near their nose portions (11), the sensed pressure differential acting to adjust the blade pitch or to align the rotor into the wind. Wind velocity may be calculated, e.g. by a computer, from the differential.

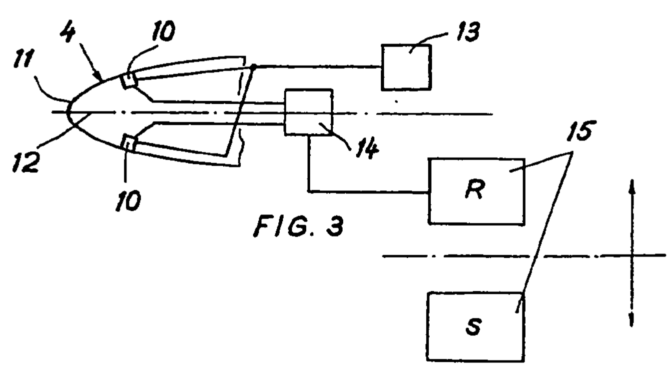

FIG. 3

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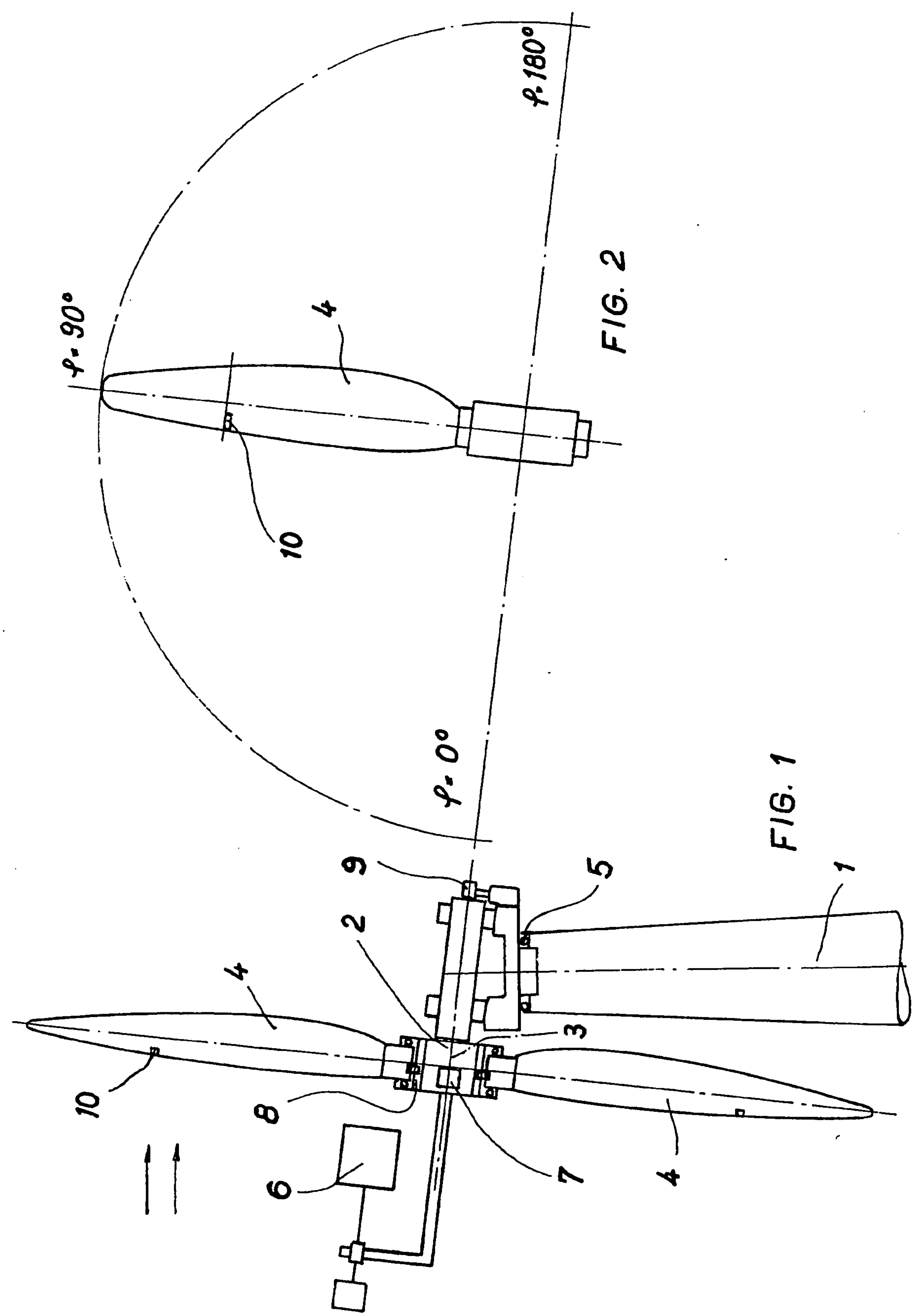

FIG. 1

FIG. 2

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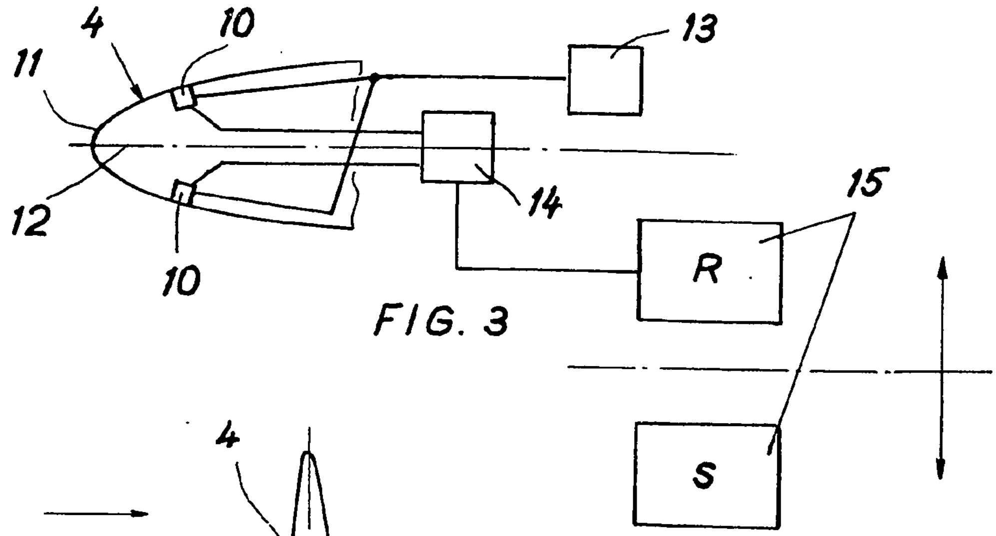

FIG. 3

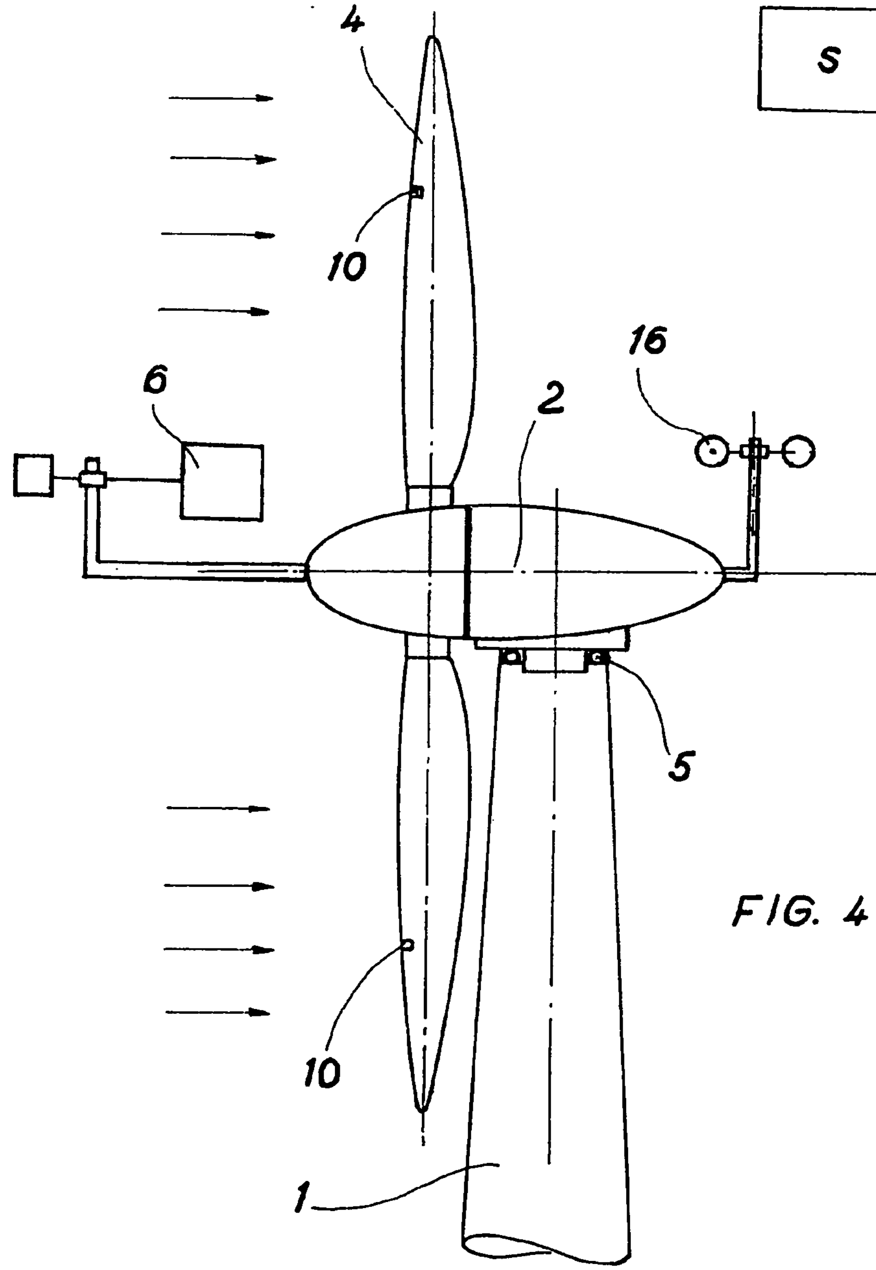

FIG. 4

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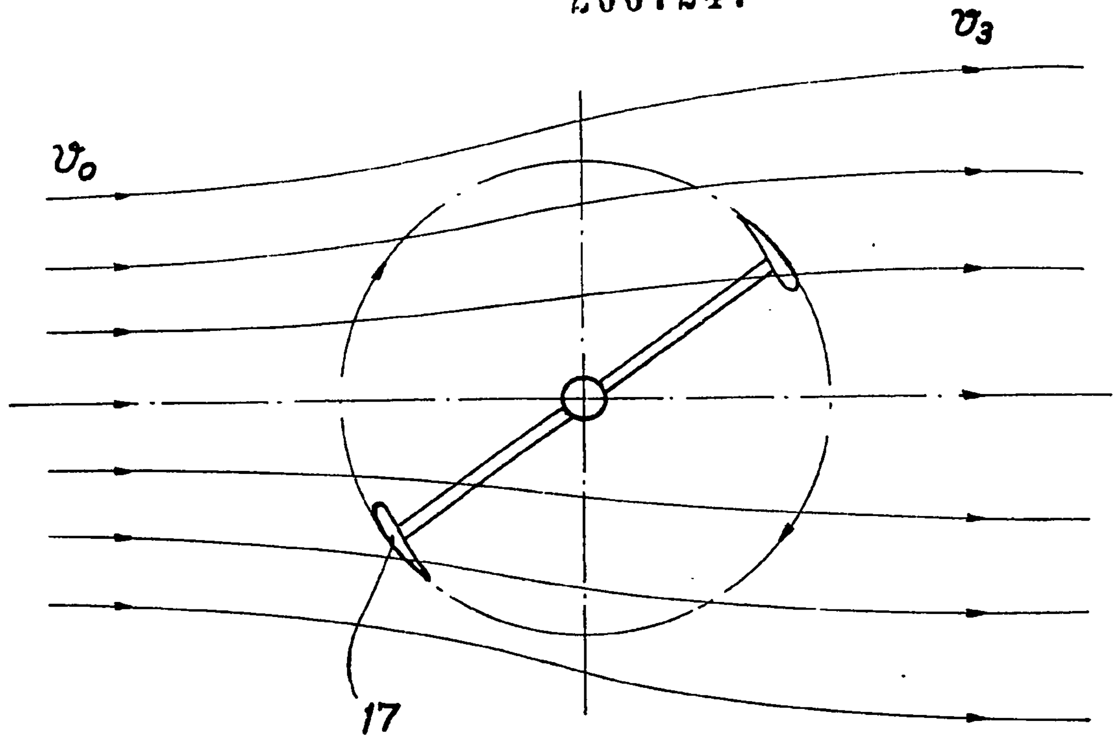

FIG. 5

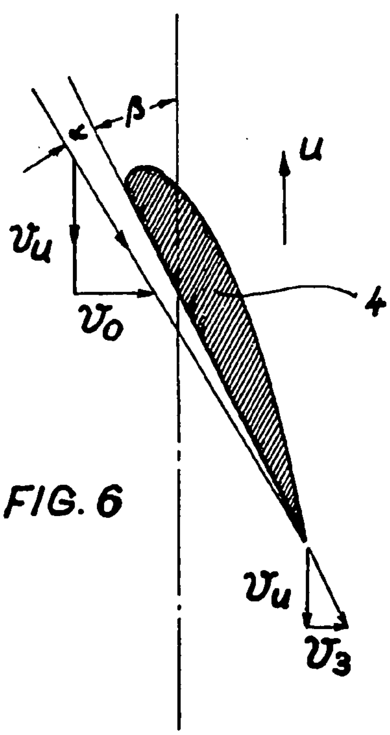

FIG. 6

SPECIFICATION

A device for determining the wind energy in order to control wind generators

The invention relates to a device for ascertaining the wind energy in the rotor plane of wind generators, whose rotors are equipped with slim, aerodynamically-shaped rotor blades, and for controlling the wind energy in the rotor plane with the aid of a pressure difference measured by probes.

The rotor blades of a wind power system transforms the energy contained in the wind into shaft power and thus produce torques which have to be absorbed by the structure of the system. This conversion of energy is all the more useful and the torques all the smaller the more effectively the system can be controlled. The following components can be affected:

the setting angle for the blade, the rotor speed, the drive output and, in the case of a horizontal rotor axis, the position of the plane of rotation of the rotor in relation to the air flow.

All of the control processes are based on the instant wind speed and the direction of the wind in the rotor plane. Therefore, it is very important to have very precise knowledge of the wind speed and wind direction at the rotor blades in order to achieve good control.

The methods of measurement, previously in common use for determining these values, produce large differences from the actual values, since they are ascertained with the aid of probes which are arranged either as close as possible to the rotor or at some distance therefrom on a special measurement mast. In the first instance errors in measurement are produced by the reaction of the rotor on the air flow; ideally, the rotor reduces the wind speed in its plane to approximately 1/3 and thus has a not inconsiderable effect on the flow immediately around the rotor. In the second instance, errors arise from lack of uniformity of the air flow, called gusts, which are produced chiefly by friction of the air with the ground and by thermal effects. The gusts are often localized to within such a small area that a wind speed measured by a mast itself located nearby may differ considerably from the speed in the rotor plane and therefore control errors arise. All of the previously known methods of measuring the wind are unsuitable for wind generators because they result in errors in control and therefore cause losses in the utilization of the wind energy produced and overloading of the structure of the wind-powered systems.

The invention seeks to provide a measuring device which is especially suitable for wind generators and in which the above mentioned errors are reduced or avoided.

According to the invention, there is provided a device for ascertaining the wind energy in the rotor plane of wind generators whose rotors are equipped with slim, aerodynamically shaped rotor blades, and for controlling the wind energy at the rotor plane with the aid of a pressure difference measured by probes, wherein the pressure probes are arranged at the surface of the rotor blades near their profiled nose or tip portions.

Pressure probes are therefore arranged at the surface of the rotor blades near the profiled nose or tip portion. In addition, a pressure probe for determining the total pressure may be arranged in front of the shaped nose or tip portion of the rotor blade. It is desirable for the probes to be arranged on the rotor blade at a point which is determined by the power characteristics of the rotor.

In order to achieve more accurate measurement, it is possible to take measurements at several points of the blade. A blade subdivided in the direction of its span width can be more accurately controlled in stages by means of this refined measurement.

Wind-powered systems having a device in accordance with the invention may be manufactured at lower cost than previous conventional systems which require a special measurement mast. The device may be used in all wind generators equipped with aerodynamically-shaped, slim rotor blades. It improves the possibility of controlling the rotor for setting the blades and aligning the rotor in accordance with the wind.

The invention will now be described in greater detail, by way of example with reference to the drawings in which:—

Fig. 1 shows a part of a wind-powered system with a horizontal axis rotor;

Fig. 2 shows a rotor blade of the system of Fig. 1;

Fig. 3 shows a cross-section through the profiled nose or tip of a rotor blade (e.g. Fig. 2) with pressure probes in accordance with the invention;

Fig. 4 shows a wind-powered system with a rotor having a horizontal axis and having a device in accordance with the invention;

Fig. 5 shows a vertical axis rotor as seen from above, and

Fig. 6 shows a further cross-section through a rotor blade (e.g. Fig. 2).

In Fig. 1 a part of a wind-powered system is shown with a carrier mast 1 and generally horizontal axis rotor 2, the axis being designated 3 and its adjustable, slim, aerodynamically shaped wing blades being designated 4.

The rotor 2 is mounted on the mast with a ring bearing 5 such that the rotor axis 3 can be pivoted about the vertical axis into the direction of the wind e.g. with the aid of a wind direction indicator 6 fixed to the axis 3. A controller 7 and adjusting device 8 operated by a controller are housed at the hub of the motor 2 for rotating the wing-type blades 4 about their longitudinal axis. Current supply slip rings 9 on the rotor axis are provided for the controller and the adjusting device.

In Fig. 2 and more particularly Fig. 3, the arrangement of pressure probes 10 in accordance with the invention is shown. The probes 10 are arranged on the surface of the wing-type blades 4 near the profiled nose or tip 11 on both sides of

the centre plane 12, preferably at a spacing from the rotor axis 3 of 0.7 of the blade length. In Figs. 2 and 4, the location of the probes 10 is indicated by arrows and this location describes a so-called "measurement circle" during operation of the wind generator. The initial angle of the wind "α" (Fig. 6) can be deduced from the difference in pressure ascertained by the probes 10. If the setting angle "β" (Fig. 6) of the wing-type blade, the pressure difference at the measurement points and the rotary speed of the rotor are known, then the wind speed prevailing locally on the wing blade can be deduced from the measured values.

An example of the signal path of the pressure values picked up by the probes and transmitted to the control system is shown in Fig. 3. A current supply is designated 13, a coding device 14 and a measured value transfer from the rotor R to the stator S is designated 15.

With a multi-blade rotor with joint adjustment of the blades the measured values of all of the wing-type blades have to be ascertained, before the controller can ascertain the most favourable blade setting angle and then set the wing-type blades with the aid of the adjusting device.

With a rotor having individual blade setting, the controller can determine the most suitable setting angle for each wing-type blade with the aid of the measured values of the individual blade.

With a device in accordance with the invention, the wind energy in the rotor plane can be determined much more accurately than by conventional methods, such as a measurement mast, or an anemometer on the extended shaft of the rotor.

A Robinson's anemometer 16 (Fig. 4) only serves to control the system outside its actual operating range. Since an anemometer shows fairly small wind speeds more accurately than the pressure probes, the control device is switched advantageously to the anemometer when the wind drops or the rotor becomes stationary. Only when the operating speed is reached is the device switched over to wind measurement using pressure probes on the wing-type blade. It is possible to switch off the system during a storm of a predetermined seventy with the aid of measurement at the blades. In the case of a wind generator switched off because of a storm, only the anemometer is in operation.

The values of the initial angle of the wind ascertained by means of the pressure difference are passed to a computer. The computer determines the local wind speed with the aid of the known values of the setting angle and rotary speed. By also using the values for air pressure, temperature and the area of the rotor circle, the effective wind energy can be calculated in a further calculation process.

The alignment of the wind during operation can be controlled by means of pressure probe measurement at the wing-type blade as well as by using the wind indicator 6 in advantageous manner. If pressure probe measurement is used, the control system compares the inardent wind angles on a wing-type blade in the 90° and 270° rotor position (Fig. 2). If both angles are equal, then it is not necessary to correct the alignment of the rotor plane in relation to the wind; if both angles are different, then the rotor plane must be pivoted until the two angles are equal again.

When setting individual blades and also when there are large local differences in the range of air flow, it is possible for unequal initial wind angles to arise. The wind alignment system just described would react advantageously by pivoting the rotor plane, until the rotor loading is as well balanced as possible.

If, in fact, the measuring system registers unequal initial wind angles at 90° and 270° (Fig. 2), then the blades have to be adjusted in the 0° and 180° position so that the rotor plane pivots about the tower axis so as to balance the difference in the initial wind angles at 90° and 270° again. With winds which increase with height, the large forces in the upper half of the rotor circle are reduced and the forces in the lower half are increased. This control is not only able to balance out to a large extent different loadings, but can also reduce bending forces acting on the rotor shaft.

If necessary, forces exciting (oscillation) can even be kept down. Overall, there is a reduction in structure loading so that lighter and therefore cheaper wind generators may be built.

While the alignment of the wind in relation to the rotor plane can be controlled during operation by a device in accordance with the invention, alignment with respect to the wind using a wind indicator is advantageous only when starting up the rotor. A rapidly reacting setting mechanism can be made much lighter and simpler in this case than the conventional mechanism, since the torques are smaller and the safety requirements lower.

As compared to the conditions with horizontal axis rotors (Figs. 1, 2 and 4) which have just been considered, vertical axis rotors (Fig. 5) have the following differences:

the rotor does not require alignment with respect to the wind;

the rotor blades 17 are subject to cyclic changes in the incident wind angle and each rotor blade enters the stream tube of the rotor twice;

the air affected is not disrupted during the first pass (windward side);

On the second pass (leeward side) the blade rushes through a decelerated and turbulent air flow.

The described method of measurement for the initial wind angle on the horizontal axis rotor (Figs. 3 and 6) operates without inertia and can also be used in vertical axis rotors. It is possible to deduce the prevailing wind speed from measurement of the initial wind speed as the blades pass through on the windward side if at the same time the rotary speed of the rotor is known. When the displacement of the blade is not controlled, exactly definable initial wind angles are provided for each rotor position for known ratios of v_u/v_o. It is

possible to deduce the locally prevailing wind speed and thus the quantity of energy in the cross-section of the rotor immediately from the values of rotor speed and position and initial wind angle. In the case of rotors with controlled blade adjustment, it is necessary in addition to know the setting angle (β) (Fig. 6) as compared to a zero position in order to carry out this measurement.

In the case of air flow on the leeward side which is decelerated and turbulent, the initial wind angles at the rotor blade can no longer be accurately determined. Control is possible, however, because of the continuous measurement of the initial wind angle on the windward side.

CLAIMS

1. A device for ascertaining the wind energy in the rotor plane of wind generators, whose rotors are equipped with slim, aerodynamically shaped rotor blades, and for controlling the wind energy at the rotor plane with the aid of a pressure difference measured by probes, wherein the pressure probes are arranged at the surface of the rotor blade near their profiled nose or tip portions.

2. A device according to Claim 1, wherein a pressure probe for ascertaining the total pressure is arranged before the profiled nose or tip portion.

3. A device according to Claim 1, wherein that the pressure probes are arranged at a spacing of 0.7 of the length of the blade from its rotor axis.

4. A device according to any one of Claims 1 to 3, wherein an anemometer is provided for the purpose of determining the range of application of the wind generator.

5. A device according to any one of Claims 1 to 4, wherein an anemoscope is provided on the rotor axis extended in a windward direction at a distance from the rotor plane of 0.2 to 0.5 of the blade length in order to align a rotor system with a horizontal axis in relation to the wind.

6. A device according to any one of Claims 1 to 5, wherein the rotor is aligned in relation to the wind with the aid of angular control of the blades.

7. A device for ascertaining the wind energy in the rotor plane of wind generators substantially as described herein with reference to the drawing.

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